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Using Wicked Problems to Foster Interdisciplinary Practice Among UK Trainee Teachers

Key words: Wicked problems; interdisciplinarity; teacher education

Abstract

An uncertain world characterised by the complexity associated with 'Wicked' problems presents formidable challenges for the preparation of teachers. This paper reports on one cycle in a larger action research project in which subject specialist trainee teachers worked in inter-disciplinary groups to design and run classroom-based workshops on climate change for students aged 12-14. While the project sought to explore interdisciplinary working, subject specialisms and their values were not abandoned, recognising that diversity can lead to more powerful, collective knowledge being generated. The Wicked problem of climate change was initially examined from different subject perspectives, identifying the opportunities that the work afforded in each subject, along with the challenges that accompanied them. The findings suggest that trainee teachers valued the collaboration and the opportunity to develop different pedagogical approaches used by different subjects. The framing of the project around a Wicked problem supported trainee teachers in understanding that no one subject had an authoritative prerogative over the topic while the disquiet that the interdisciplinary project provoked, in some cases, served to instigate new transformative learning which stretched beyond traditional disciplinary boundaries.

Using Wicked Problems to Foster Interdisciplinary Practice Among UK Trainee Teachers

Introduction

In the early years of the UN Decade of Education for Sustainable Development (2005-14) (UNESCO), *JET* commissioned a special issue concerned with policy and practice in relation to education for sustainable development, identifying the progress that had been made and the challenges which needed to be addressed (Gilroy, 2007). The messages from that special issue pointed to the need to reorientate the training of teachers towards sustainability while also recognising that context matters and that existing 'one size fits all' models are inadequate. Ferreira et al. (2007) identified different models of teacher education which were supportive of this reorientation including the capacity building benefits afforded by action research.

The UN Decade is over. Reviews of the decade have drawn attention to the significant challenge of introducing environmental education in a neoliberal climate (Hursch et al., 2015) while others have suggested that successes were limited and it's still 'business as usual' (Huckle & Wals, 2015). On the other hand, the importance of preparing teachers, and the students they teach, for an emerging changing world, along with the value of action research, continue to be stressed (Flores & Al Barwani, 2016; la Velle, 2017).

In the years since JET's special issue, discourses around sustainability have shifted. In 2007, Shallcross and Robinson suggested, in still relatively upbeat mood, that universities should model sustainable development (SD) for teachers along with providing 'knowledge as a public good and this role includes providing knowledge about SD' (2007, p. 143). In contrast, the discourse today has become less certain in its tone. Many of the challenges facing societies and the planet have increasingly been conceptualised as 'Wicked' problems. We characterise these as unique and highly complex issues that defy complete definition, and for

which there can be no clear solution since any resolution generates further issues (Brown et al., 2010); Wicked problems are intractable, with multiple stakeholders and competing perspectives, with the implication that we must learn to live with an uncertain future as an endemic condition, and innovate to create solutions to problems that have either not been seen before or, at least, not on this scale (Finley, 2014; Dillon et al., 2016). Drawing from this conceptualisation, we argue that there are implications for education which teacher education needs to address: Firstly, teacher education must raise awareness of the nature of Wicked problems and provide opportunities for trainee teachers to consider such issues in their own practice since, although it would be inappropriate to look to schools as the source of solutions, students are the people who will have to grapple with the Wicked problems the world faces in the future; secondly, since Wicked problems are multi-causal and interconnected, there is a need to look beyond strict traditional disciplinary boundaries, which dominate in the English education system, to consider more interdisciplinary frameworks (Pryshlakivsky & Searcy, 2013). As teacher educators, our aim is to support trainee teachers in becoming not simply competent teachers able to deliver a prescribed curriculum and thereby 'fit in' and thrive in a subject-based environment, but also critically reflective practitioners, who develop confidence in thinking through values and purposes and in independently shaping and crafting a curriculum to support learning. Our aim is to encourage trainee teachers to find those spaces within a constrained school curriculum where they can begin to address knowledge that is difficult, counter-intuitive or 'alien' (Perkins, 1999) such as that associated today with Wicked problems.

The project reported here focuses on the Wicked problem of climate change. It adopts action research methodology and is the second cycle of ongoing research within our School of Education exploring issues surrounding interdisciplinary work in teacher education. The first cycle was reported in subject journals (Hawkey et al. 2016; James et al., 2016) where we initially prioritized subject specialist inputs, addressing climate change from three subject

perspectives before coming together for a more interdisciplinary action-focused plenary. In this, the second cycle, we move more towards interdisciplinarity in keeping with our understanding of the challenges involved in engaging with Wicked problems.

While the research explored interdisciplinary working, it did not call on us to abandon subject specialisms. While maintaining our overarching characterisation of Wicked problems, we initially contextualised and examined the issues from our individual perspectives. We outline the opportunities that the work afforded in each subject, along with the difficulties, before addressing the interdisciplinary challenges experienced across the three subjects.

Different Subject Perspectives

Science

Wicked problems

Wicked problems present a particular challenge for science trainee teachers given the positivist and empiricist paradigms that underpin traditional scientific knowledge which is often characterised as objective, and context and value-free. Where science is applied, it tends to be exercised in relation to what might be termed 'tame problems' where there are a limited number of variables, and low-levels of uncertainty and stakeholder involvement (Frame, 2008). Our science trainee teachers have experienced this phenomenon in their own education and even those who have come from careers in what might be termed 'professional science' will have at most encountered 'science consultancy', which can entail somewhat higher levels of uncertainty and stakeholder involvement (Funtowicz & Ravetz, 1993), but will generally involve application of tame initiatives.

The school science curriculum enshrines the subject in an objective manner where even areas such as climate change are conceptualised simply as objects to be studied. The latest version of the English Key Stage 3 (students aged 11-14) national curriculum for science (DfE,

2014a) highlights this approach stating that 'pupils should understand that science is about working objectively, modifying explanations to take account of new evidence and ideas and subjecting results to peer review' (p.3). There are those, though (e.g., McFarlane, 2013), who call for the reconceptualization of science in ways that will enable us to grapple with the global problems, leading to a curriculum that will be more action-focused and responsive to the dilemmas that we face.

The characteristics associated with issues such as global climate change do not typically sit comfortably with trainee science teachers as their backgrounds predicate a liking of certainty, where methods and knowledge can be applied to stable, testable situations so that solutions can be generated for implementation or rejection. Such dualist approaches place agency in quantitative knowledge, authority and right solutions (Olson & Finson, 2009), yet are not necessarily helpful for trainee teachers seeking to develop their teaching practice in classroom environments that are themselves complex, evolving and frequently contradictory.

History

Wicked problems

The purpose of history education is to help students to 'gain a coherent knowledge and understanding of Britain's past and that of the wider world' (DfE, 2014b, p. 1) As such, the focus is not only Anglocentric but also one which prioritises the nation as the unit of analysis. While the emphasis has varied in different iterations of the English national curriculum, these foci have always been present. Elsewhere, there is the same focus on national history, reflecting a longstanding and widespread tradition of school history being a 'self-congratulatory' tool for 'social cement' (Aldrich & Dean, 1991, p. 102). On the face of it, there is little scope for school history to think about Wicked problems, many of which stretch beyond national boundaries. This traditional national approach has, unsurprisingly, been critiqued and curriculum development in the UK since the 1970s has led the way globally in

developing alternative approaches. The Schools History Project (1976) set out the disciplinary underpinnings of the subject anchored in concepts such as enquiry, causation and change and these have shaped the requirements of all iterations of the history national curriculum alongside any national emphasis specified. These disciplinary concepts offer potentially valuable foci for engaging with Wicked problems with, for example, opportunities to focus on complexities in causation in ways that a curriculum focused on national narratives does not.

History is 'the unending dialogue between past and present' (Carr, 1961, p. 4) and what is of significance today is one factor in deciding what should be taught in schools. Guldi and Armitage (2014) argue that Wicked problems such as climate change, require historians to use more long-term thinking to connect past and future, 'using the past to think critically about what is to come' (p.13). In school history education, Shemilt pushes the point further, arguing for history to be seen along a continuum of past, present and future, 'the disposition to investigate and analyse the past from the perspective of possible futures is a key development in historical consciousness and one that transcends the all too common perception that "the past is dead and gone" (Shemilt, 2009, p.197).

A focus on Wicked problems, their historical roots and possible future developments, is certainly relevant to studying history although thinking about possible futures is something that trainee teachers are unlikely to have had experience of either as undergraduates or in their teaching in schools. Furthermore, while the history national curriculum stipulates students should understand 'the connections between local, regional, national and international history; between cultural, economic, military, political, religious and social history' (DfE, 2014b, p. 2), there is no mention of any scientific or environmental causes or impacts which thinking about Wicked problems is likely to involve. This narrowness has been critiqued with calls for a curriculum to have more porous boundaries between human and natural history (Aldrich, 2010), as well as arguments for seeing human history as just one episode in the much longer history of the universe (Christian, 2005). These critiques, however, have had little impact on

the rubric of any history national curriculum in England and trainee teachers will typically have little experience of teaching beyond the established subject parameters.

Geography

Wicked problems

When compared to science and history, Wicked problems seem to sit relatively comfortably in geography, a point argued by Roberts (2017), 'the big issues of our time, such as climate change, ensuring future supplies of water, food and energy for the world's growing population, the global gap between rich and poor are more likely to be studied in geography than any other subject' (p. 7). Climate change is mentioned as a topic both in the current version of the Key Stage 3 (students aged 11-14) geography national curriculum for England and the current compulsory core content for GCSE (students aged 14-16) (DfE, 2014c) thus recognising that key elements, such as weather and climate systems, are geographical in nature.

While content is one part of addressing Wicked problems, another element is pedagogical approaches that encourage critical engagement with that content, supporting students to grapple with uncertainty and complexity. Such approaches are well-established in school geography including geographical enquiry, where asking questions, and using various sources of data to search for possible answers, are central (Davidson & Catling, 2000; Roberts, 1996; 2014). Recently, Roberts (2017) has described the enquiry approach, alongside dialogic talk and Socratic discussion, as powerful pedagogies that enable students to grapple with controversy, recognising that understanding Wicked problems requires awareness of values as well as facts.

The central tenets of enquiry, of researching questions that have no one correct answer have recently been incorporated into the framework underpinning the Geocapabilities project. This European Union funded initiative examines what the study of geography contributes to a young person's education in the 21st Century and highlights a focus on alternative futures (Bustin et al., 2017). However, these priorities of the Geocapabilities project contrast with the current national curriculum and the GCSE specifications in which climate change, as a topic for study, is studied only up to the present day thus failing to raise questions about uncertain futures that are integral to Wicked problems. These specifications, therefore, are more aligned with the tame problem approach described in relation to the Science curriculum. Also, when considering the current use of powerful pedagogies in the geography classroom, there are signs of this being diminished due to the demands of meeting the requirements of exam specifications, referred to by Ferretti as 'the pressures of the performativity agenda' (2013, p. 103).

Interdisciplinary working

Interdisciplinary working presented different challenges for trainee teachers from each of the three subjects.

Science:

Working in interdisciplinary ways can present significant challenges as the subject itself struggles to transcend the different disciplines of biology, chemistry and physics and students on the one-year Postgraduate Certificate of Education (PGCE) Science programme can face difficulties in relinquishing something of their individual subject identity in even teaching science.

Apparent attempts to foster interdisciplinary working have been made through the rise of STEM (science, technology, engineering, and mathematics) at the start of the 21st century (Blackley & Howell, 2015). Its inception would seem to have afforded opportunities for

teachers to move out of their narrow subject areas and adopt more innovative, collaborative approaches. It can be argued though that the notion of STEM was introduced in the UK for political reasons, to enhance economic competitiveness in a global world by increasing interest in STEM subjects and generating more scientists (Wong et al., 2016). However, there is little evidence for STEM making a difference to either agenda; in terms of education, the STEM subjects are rarely taught in integrated ways (Reiss & Holman, 2007) and countries that have adopted a STEM agenda have often seen a fall in numbers, particularly from underrepresented groups, opting for STEM subjects and a decline in performance in comparative international tests (Blackley & Howell, 2015). While technology and mathematics might appear to be the natural allies of science, there may be value in aligning science education with the humanities when considering how to address global challenges and in encouraging young people to be active participants in science education**.**

Such an approach can feel threatening for scientists as they tend to take the view that their subject deals with objective knowledge while other humanities subjects deal with values (Allchin, 2001). It was important, therefore, in this initiative that science trainee teachers saw they were not being asked to abandon their discipline, but to embrace the values that science asserts (cultural, epistemic and ethical) and those offered by other subject areas. So, it was hoped that science trainee teachers might deepen their understanding of the nature of science, and appreciate pedagogical approaches that might help students in school to see how values intersect with science.

History:

Unlike science and geography, where climate change is mentioned within the subject curriculum, a priority was to make the case, with the history trainee teachers themselves, for history having a valuable contribution to make to a project of this nature. The aim was to locate current climate change into a much larger history across time, and to develop an understanding of a 'little big history' (Quadackers, 2014) of climate change.

While teaching new topics is routine, teaching one which stretches beyond the expected boundaries of the history curriculum was bound to raise anxieties. Prior to interdisciplinary work, therefore, the history tutor provided an overview of historical knowledge of climate change for the history trainee teachers, drawing out the links and connections between natural and human causes and effects. Having introduced this new overview knowledge, there was also a need to proactively give them the opportunity to practise their teaching in this novel area. When the workshops were taken into schools, therefore, the history trainee teachers led a session teaching a 'little big history of climate change'.

This process resulted in a paradoxical situation in that while the trainee teachers from all subjects were asked to engage with the creative challenge of finding meaningful ways to work in an interdisciplinary manner to support student learning about a Wicked problem, the history trainee teachers were asked to do something additional in order that they could practise teaching an aspect of history none had experience of doing before. In practice, the history trainee teachers felt a clear sense of accountability in implementing a particular set of activities while the expectations and plans for the interdisciplinary elements to which all subjects contributed were left much more open.

Working in an interdisciplinary way which required discussion with peers with different specialist knowledge was, arguably, a minor challenge. History, as a discipline, is rooted in interpretation along with an openness to varied perspectives; to work in groups with different specialists was relatively familiar territory for the historians. A greater challenge came with demonstrating to the trainee teachers at the outset that history had something distinctive and worthwhile to contribute to a project on Wicked problems.

Geography:

Geography is often viewed as a bridge between science and humanities, with this being considered by many as a fundamental strength of the discipline. Indeed, geography shares

significant elements of content with science and this, along with commonalities in pedagogies with history, suggests that in an interdisciplinary project such as ours, the geography trainee teachers will have an authoritative voice in taking the lead in planning and running the workshops. However, the perspective of geography as a 'bridging' subject, with its underlying assumption that the nature of geography itself is uncontested, is not reflected in how geography trainee teachers view their subject. Amongst the geography trainee teachers there were differences in perspectives on the basic nature of geography depending on the type of undergraduate geography degree they had studied, with three different routes represented - science, arts or social sciences. As Hawley says, 'what lies at issue here is the prevailing divide between human and physical geography in schools' (2013, p. 93).

Another challenge to the 'bridging' perspective is that, in most UK schools, geography is placed in the humanities faculty meaning that daily contact is predominantly with history and RE colleagues. This positioning perhaps goes towards explaining why many of the geographers, like the history trainee teachers, were reasonably comfortable working with the different perspectives that interdisciplinary groups brought. A further challenge, for some geography trainee teachers, was an acknowledgement that despite climate change's inclusion in curricular documents it was not easy to 'take the lead' with clear authority. However, they were able to share previous experiences of teaching climate change within the interdisciplinary groups and they drew from a familiarity with thinking about different ways to frame the issue of climate change. They brought to the discussions some of the following approaches advocated by Roberts (2013): climate change as a scientific dispute: anthropogenic or natural?; as an environmental issue; as an issue about differential impact and social justice; as a security issue; and, as an economic issue. Geographers were also able to contribute an extensive understanding of place and the complexities that specific locational and spatial contexts bring to a project on climate change.

Aims and research question

Our aims were:

- To explore how interdisciplinary approaches might be used in teaching climate change as a Wicked problem;

- To extend PGCE trainee teachers' pedagogical repertoire and understanding by taking an interdisciplinary, collaborative approach to studying climate change as a Wicked problem.

Our research question was, 'How does a focus on the Wicked problem of climate change influence trainee teachers' attitudes to collaborative, interdisciplinary work?'

Participants

All participants were in the same cohort of postgraduate trainee teachers at the same university. They were in their last term of a one-year PGCE programme (the main pre-service teacher education route leading to qualified teacher status). The project did not contribute to any formally assessed assignment. There were a disproportionate number of scientists compared to geographers and historians and it was recognised that this imbalance in numbers might create a barrier to the extent to which interdisciplinary work could take place.

Trainee teachers were assigned in multidisciplinary groups ranging in number from nine to eleven and tasked with implementing the climate change project in different local schools who wanted to get involved. Although not intentional, the schools could be viewed as representative of England's socio-economic diversity. Each of the six schools involved managed the project slightly differently, however, in all cases the school students were aged 12-14-years-old and were recruited by the school. Group sizes ranged from 35 to 60, but were

then split into more manageable teaching groups and were arranged into more than one class. The time allocated for the workshops was two hours.

Teaching Intervention Design

The teaching intervention took place over three days. On day one, trainee teachers met in their subject groups. The aim for this day was to ensure a shared understanding of the nature of Wicked problems across the three subjects. To achieve this, common guidance and teaching notes were created including a discussion about the repair of the ozone layer to illustrate the nature of a 'Tame' problem in contrast to climate change as an example of a Wicked problem. Trainee teachers were invited to consider the question, 'what are the implications of Wicked problems for teaching my subject?' On the second day, the trainee teachers shared these subject discussions about Wicked problems in interdisciplinary groups before preparing their workshops supported by tutors. A key consideration on this day was to ensure that any planned activities were appropriate to the age and needs of the school students and careful attention was given to ensuring that all interventions were ethically sound. Some of the resources and activities developed and used included: a time-line focusing on a little big history of climate change; an activity linking environmental and human causes and impacts of climate change; an enquiry focusing on 'what is my carbon footprint'?; an enquiry focusing on 'will I be affected by flooding in Bristol 2020 & 2050?'; country briefings on local impacts of climate change; and, possible energy sources for use in a UN summit role play. On the third day the workshops were taken into local schools.

Data Collection and Analysis

Data were collected on the trainee teachers' perceptions of the project intervention through an online questionnaire survey. Arising from our research question, we prioritised the interpretative approach, asking open ended questions in the survey and did not seek to make

predictions about outcomes. We were alert to potential limitations in our role as both subject tutors and researchers who were present as observers during the preparation stage as well as the workshops themselves. As a result, although our observations contributed a second data source from which to draw, we prioritised the survey results as the primary data source.

Following the workshops in schools, trainee teachers were invited to complete the online survey. Sixty-three PGCE trainee teachers participated in the climate change workshop teaching in school of whom 36 took part in the survey (22 scientists, 7 geographers, and 7 historians).

The answers to the open-ended survey questions were analysed thematically using an inductive approach as described by Braun and Clarke (2006) to identify and report themes. This approach was chosen as most appropriate since the research aimed to explore the process of engaging in the interdisciplinary climate change project from the participating trainee teachers' perspectives. Tutors analysed the data individually looking for emerging patterns and then, recognising our own subjectivities, worked collectively to define and review themes.

Ethical considerations

Formal ethical consent for the project was not sought because it was considered that the initiative was part of the trainee teachers' standard training practice; they are also regularly invited to evaluate their training using a variety of means, so trainee teachers were accustomed to providing feedback in the manner outlined above. To have sought formal consent may have caused the trainee teachers to behave and act differently. However, it was made clear to participants that provision of feedback was voluntary, and done on a basis of anonymity, other than there being identification of subject discipline. Punch (2009) identifies disadvantages to insider research relating to possible vested interest in the results, which made it important to recognise our position as tutors having authority over the trainee teachers. The

project took place though at the end of the academic year, with all formal assignments completed, so reducing the likelihood of the trainee teachers seeking to please.

The project was explained clearly to the participating school staff although teachers in the schools did not take an active part in the workshops. Schools used their 'in-house' permission systems for student involvement.

Findings

The analysis of the trainee teachers' perspectives identified key categories which will be described briefly before a more detailed discussion of the findings.

1) Learning about collaboration in multidisciplinary teams

A high proportion of the trainee teachers reported learning from other subject areas, in terms of opening their eyes to different strategies and highlighting the relationships between subjects. Some noted that learning from other subject areas could be discomforting and there was a perception that it had added to their planning time.

2) Benefits of interdisciplinary working

The main benefits revolved around learning new pedagogical approaches, subject content from other disciplines and the links between them. Pragmatic values were also noted, for example the sharing of the workload, and the development of collaborative and team skills. Some suggested that the more holistic approach, enabled by the interdisciplinary working, had been motivating.

3) Challenges of interdisciplinary working

The trainee teachers felt that the key challenge was the large size of the groups, resulting in the generation of a considerable number of ideas that took time to discuss and distil. The lack

of a clear structure, e.g., no prescribed lesson format or objectives, appeared to be a significant challenge for some trainee teachers, along with concerns about not knowing the students who they would be teaching. Although the trainee teachers were brought together for the project, only one expressed the view that their lack of knowing each other had impeded the work.

4) Benefits to the school students from working in this way.

Two key benefits emerged: firstly, that the project had helped students to contextualise ideas and make links across subject boundaries, and secondly that bringing together different subject perspectives had resulted in a variety of activities that facilitated high levels of student engagement. Adding to the latter factor was the sense that the trainee teachers had inspired each other and that this had transferred itself to the school students. The promotion of critical thinking was another benefit reported by some trainee teachers.

5) Challenges to the school students

Many of the expressed challenges were the converse of the perceived benefits: that there were too many different teachers involved and that the variety may have proved confusing for some students. A few felt that some students had not coped very well with the change of routine and others had struggled with the subject concepts. Other concerns centred around the lack of follow up after the workshop, and that the activities had been overly teacher-led, not permitting students the time to develop their own ideas.

6) Improving the activity

A recurring suggestion was that more time was required for the preparation phase, and that trainee teachers came to the interdisciplinary planning meetings with clear ideas about how a climate change workshop might be delivered from their subject perspective. Pragmatic points were made about the need for better communication with the schools and the length of the

workshop. A number also felt that a collaborative pedagogy should have been introduced earlier in the training year and more opportunities provided to practise it.

Discussion

Subject knowledge and pedagogy were identified as key benefits of collaboration by the participants. Some expressed surprise as to the level of benefits that resulted from the collaboration, e.g., '*There are more possible cross-overs between subjects than I originally thought*'; and '*Learning more possibilities for this than I had previously thought possible*.' Trainee teachers expressed a positive view of collaboration that they want to take forward into their teaching career, e.g., '*I found really interesting links with both Science and History that'll be used in my future lessons'*; and '*Different perspectives on content has inspired me to work with other departments next year*'.

The project was carried out towards the end of the PGCE training period, so it is understandable that functional and pragmatic reasons were given as the main benefits of the interdisciplinary collaboration; trainee teachers appreciated learning about new teaching strategies and the different terminology used in other subjects. The project helped trainee teachers to value seeing other pedagogical approaches in action, e.g., '*Very useful 'cross-fertilisation' exercise for observing how other student teachers have developed and approaches in other subjects'*. Learning about relationships with other subjects featured and benefits were expressed in epistemological, as well as pedagogical, terms, e.g., '*Subjects can have very different objectives*'. While two trainee teachers suggested it was difficult to integrate the history inputs into the workshops, perhaps reflecting a view of the subject having little to contribute to a project outside of history's traditional domain, examples contributed by the historians were also the ones which other trainee teachers commented on as having greatest scope to enrich their own subject teaching on climate change, e.g., '*Linking historical*

events such as witchcraft to past climates will be used in my future lessons'; and '*I learnt a lot from different perspectives, e.g., why buttons and buttonholes were invented*'; and '*I would definitely use the history activity if I was teaching about the paleoclimate again*'.

While there was optimism around collaboration, there were also challenges which arose from the perceived different priorities that subjects have, e.g., '*Some subjects have very different techniques for teaching (Geography - more enquiry-based, which Science seemed unused to)*'. This observation might reflect the perception of science trainee teachers that teaching the subject is all about 'telling' and not about 'enquiring'. On the other hand, while science teachers may be more prone than others to feeling discomfort reflecting on the nature and purposes of scientific knowledge (Malthouse et al., 2014), it was interesting to note references made by science trainee teachers to the project broadening their outlook and approaches, providing a situation for science to be put into context, e.g., '*Students benefited from a workshop which had a political and human focus but also embedded science within this'*. There were very few comments conceptualising the project as 'soft science', i.e., that students weren't being taught 'proper science'.

The challenges of collaborative working for trainee teachers tended to focus on the logistics of organisation and lack of time. Very few questioned the project in terms of its aims and principles, though some noted challenges related to relinquishing control, e.g., '*The three subjects approach the topic in very different ways, so it has been important for everyone to give up some control and be open to new approaches and methods'*.

These comments reveal that, for some, the project itself had characteristics of a Wicked problem and thus helped to develop their understanding of Wicked problems: Outcomes were difficult to define, unlike much of the more standardised performance that trainee teachers experience during their training programme, the situation was unique, with a diverse group of trainee teachers coming together to plan and teach, and individual trainee teachers will have

viewed the process through very different lenses. Hence getting agreement about the nature of the challenge was important and it was noticed that trainee teachers, at the planning stage, spent considerable time in debate and negotiation about the problems and opportunities that the project afforded. Although not featuring in evaluation comments, trainee teachers' discussions at the planning stage often coalesced around the knowledge of climate change that they were bringing from their individual subjects. This phenomenon highlighted that, for a Wicked problem, such knowledge is often contested and uncertain (Dillon, 2016), and hence prompts negotiation, collaboration, and the opportunity for a shared community of enquiry.

The framing of the project around a Wicked problem may have helped trainee teachers to manage a loss of disciplinary control as their concerns were put into perspective through examining a problem that has itself high levels of uncertainty associated with it. For some, the difficulties this approach presented were most noteworthy, e.g., '*Lack of control, uncertainty about how things were planned'*; while for others the approach contributed to the value and worth of the project, e.g., '*Real freedom given in the brief to allow for creative approaches to be trialled'*. In contrast to the predictable and prescribed outcomes which characterise much of teaching, not having that requirement may have enabled more meaningful development for some. It can be difficult for trainee teachers to see the richness that unpredictability and tentativeness can add to the classroom, but our analysis indicated that trainee teachers did not perceive the lack of tangible outcomes, both in terms of student outcomes and their own practice, to be a concern. Royle (2003) has suggested that uncertainty and ambiguity are actually critical dimensions of effective teaching, 'intellectual uncertainty is not necessarily or simply a negative experience, a dead-end sense of not knowing, or of indeterminacy. It is just as well an experience of something open, generative, exhilarating' (p.52).

Our findings raise a question as to whether subject teachers could only collaborate over Wicked problems and whether 'tamer' problems would be seen as soluble within a subject discipline, where perspectives from other subject areas might be seen as offering limited

value; trainee teachers may view tame problems as ones to which subject knowledge can be applied with a degree of certainty and hence will 'work well' in their lessons. The focus in schools tends to be on the disciplines, whose boundaries are formed by practice and use of technical language, and how they can solve problems, and not on the nature of the problems themselves (Bore & Wright, 2009). Indeed, the specification for teaching in the science and geography national curricula suggests climate change is a 'tame' problem which can be addressed 'objectively' and there is an absence of any of its 'Wicked' characteristics such as uniqueness and uncertainty; in the history curriculum, the mention of climate change is absent altogether.

The optimism expressed by trainee teachers about collaboration in this project may well diminish when they start their teaching jobs and are faced with the current regime in schools which places high emphasis on standardised testing, predictable planned outcomes, and accountability. Priority is inevitably given to those areas that are being tested resulting, in secondary schools, in teachers shying away from interdisciplinary work (Stevenson et al., 2014). If teachers are to believe that working in this way has merit then there is a need for reassurance that collaborative approaches do not undermine performance in standardised tests, however there is a paucity of research to provide evidence for the effectiveness of interdisciplinary approaches (Blackley & Howell, 2015).

Conclusions

We had considered that the notion of Wicked problems could be helpful in opening up avenues of thought across different subject perspectives, and we would suggest that our work shows some value in examining Wicked problems such as climate change through an interdisciplinary lens. A realisation for trainee teachers was that while each subject had their own distinctive knowledge in relation to climate change, no one subject had the prerogative

on its teaching, reflecting studies with in-service teachers that show a lack of consensus on where climate change should be taught in the school curriculum (Feierabend et al*.,* 2011). Hence, in framing climate change as a Wicked problem, trainee teachers were made more aware of the nature of beliefs and practices within their own subject with deeper appreciation being gained by directly engaging with other subject perspectives and contradictory views. It has prompted further reflection on the organisation of knowledge. The specifications of different subject national curricula continue to work within the long established subject boundaries broadly conceived in the Enlightenment as a means of organising a growth of knowledge at that time (Wellmon, 2016). A further burgeoning of knowledge in our own times, and the identification of Wicked problems, now call for subjects to review and re-conceptualise their practice in light of these contemporary challenges.

While recognising that our broad approach to data collection and the small-scale nature of the study limit the potential for generalising, we nevertheless would recommend the incorporation of such initiatives into teacher education programmes, not only for the potential benefits that might be gained in relation to trainee teachers' knowledge and skill development, but also in the advancement of an interdisciplinary community that can promote meaningful engagement of school students with troublesome and controversial issues. Inescapably such approaches entail a loss of control and a rethinking of subjectivities, but the disquiet experienced by some trainee teachers in this project can be seen as something purposeful, the 'provoker of change that cannot be assimilated, and hence is the instigator of new learning and new ontological possibility' (Land, 2011, p.68).

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